Space Weather Technical Forecast

Issued on Monday, 06 December 2021 at 13:09 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Numerous CME candidates in period awaiting confirming imagery. Slight chance of G1/Minor Storms day 4 from one such event.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity reverted to Low over the past 24 hours, with occasional C-class flares recorded at GOES 16 emanating from two main sources. The first of these sources produced two main long-period C-class events: these are probably attributable to a developing region over the western limb. The second long-period flare from this region was overlaid by several more impulsive small C-class flares - this a result of growth in the sole remaining front-sided sunspot in the southeastern quadrant. This one remaining sunspot, AR2904, underwent a brief growth phase involving proliferation of intermediate spots, however this receded as the period ended to leave a tenuous Beta Cro.

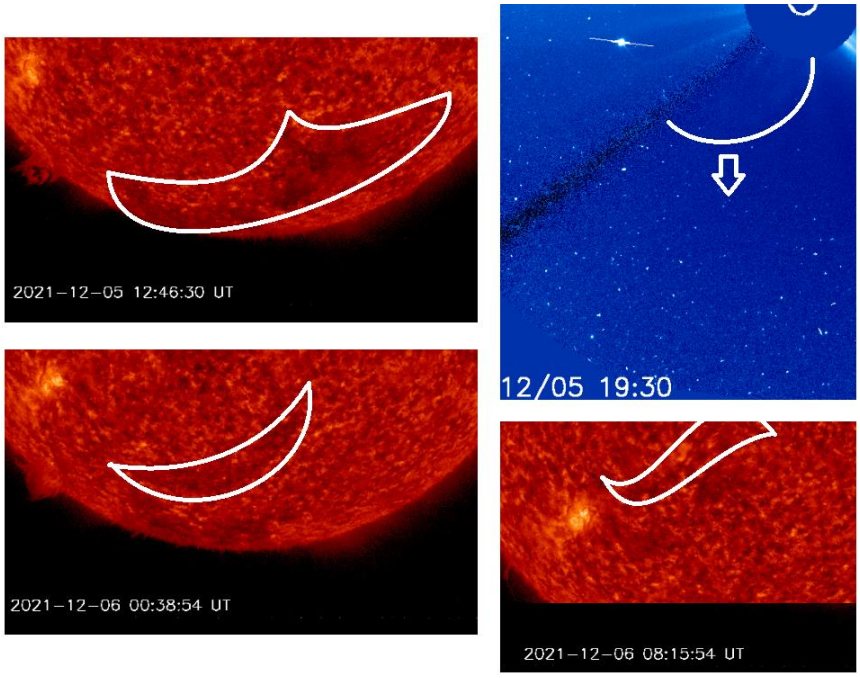


Figure 0: AIA 304 imagery of three events of interest in the period, tentatively correlated with a Lasco C3 image in the first case (top). All three potential filament lift offs could also be seen to some degree in H-Alpha imagery.

The period was also characterised by a series of potential filament lift offs. The first of these was a large low solar latitude event that occurred at the very start of the reporting period, visible in Cerro Tololo H-Alpha imagery and AIA 304. The second was faint in H-Alpha, but also just visible in Cerro Tololo in the southeastern quadrant, starting 05/1900UTC. This was more obvious on SDO AIA 304 imagery, where the filament appears much larger and its lift off spans

© Crown Copyright 2021. All Rights Reserved.

05/1900-06/0200UTC, with an eventual similar latitudinal extent to the earlier filament. Finally, the third candidate was small but more pronounced on H-Alpha, occurring 06/0600-0800UTC. This again was centred on the southeastern quadrant, with this feature visible on Learmonth H-Alpha imagery.

Coronagraph imagery for the period is relatively scant, with the added complication of the C-class flare generating region behind the western limb producing some non-Earth directed Coronal Mass Ejections (CMEs). At present, Lasco only hints at ejecta from the first of the three events, but this will be updated in due course should thoughts on this change, or STEREO A COR2 become available.

All considered, as with the previous issue of this guidance, the only 'confirmed' CME produced is that linked to the initial large southern hemisphere filament at around 05/1200-1330. This is weak and low confidence in its attribution, but carries a potential Earth-directed component arriving 09/1800UTC +/-9 hours.

Solar Wind / Geomagnetic Activity: The solar wind, as measured by DSCOVR at L1, was at slightly elevated levels 430-470km/s, but rose to 530km/s briefly around 05/2330UTC, likely due to the fast wind of CH27/28. A weak decreasing tendency then became evident through the UTC morning of Monday 06 December, with a possible late kick and phi angle change perhaps evidence of a SSBC, perhaps signalling the end of the high speed stream.

The density of the wind was around or just above average generally 8-15ppcc, although this too reverted to more typical single-figures ppcc as the period went on. The total interplanetary magnetic field strength (IMF) Bt, was weak, below 7nT, with a north-south component that was most frequently weakly negative (southward), with a range of +5/-6nT. The phi angle was predominantly positive (away from the Sun), however this changed to negative in the final hour of the period, perhaps due to an SSBC.

Resultant geomagnetic activity was generally Quiet to Unsettled (Kp 0-3), with a provisional peak Kp of '3o' in the 15/18UTC interval.

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10 MeV) remained at Background levels.

The high energy electron flux (greater than 2 MeV) was at Moderate to High levels, with a peak through the diurnal cycle of 1290pfu at 05/2010UTC. The associated 24-hour integrated fluence was below the Active threshold (1e8 integrated pfu), with 4.97e7 integrated pfu observed at 06/0000 UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: Solar activity is expected to be Low or Very Low, with the chance of further notable flares from around the limb now significantly decreased, leaving one current front-sided sunspot.

Solar Wind / Geomagnetic Activity: There are two potentially Earth-directed CMEs in the forecast, as well as two further candidates (from recent disappearing filaments) awaiting imagery.

The first CME in the forecast is from a filament eruption on Friday 03 December, scheduled to pass 1AU as a near-miss of Earth on Tuesday 07 December. A placeholder 5% risk of G1 is included as a result. The second CME is a faint emission from a filament eruption on Sunday 05 December, and is expected to arrive day 4 (Thursday 09 December) at 09/1800UTC +/-9 hours, but again confidence is low due to limited imagery for analysis.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

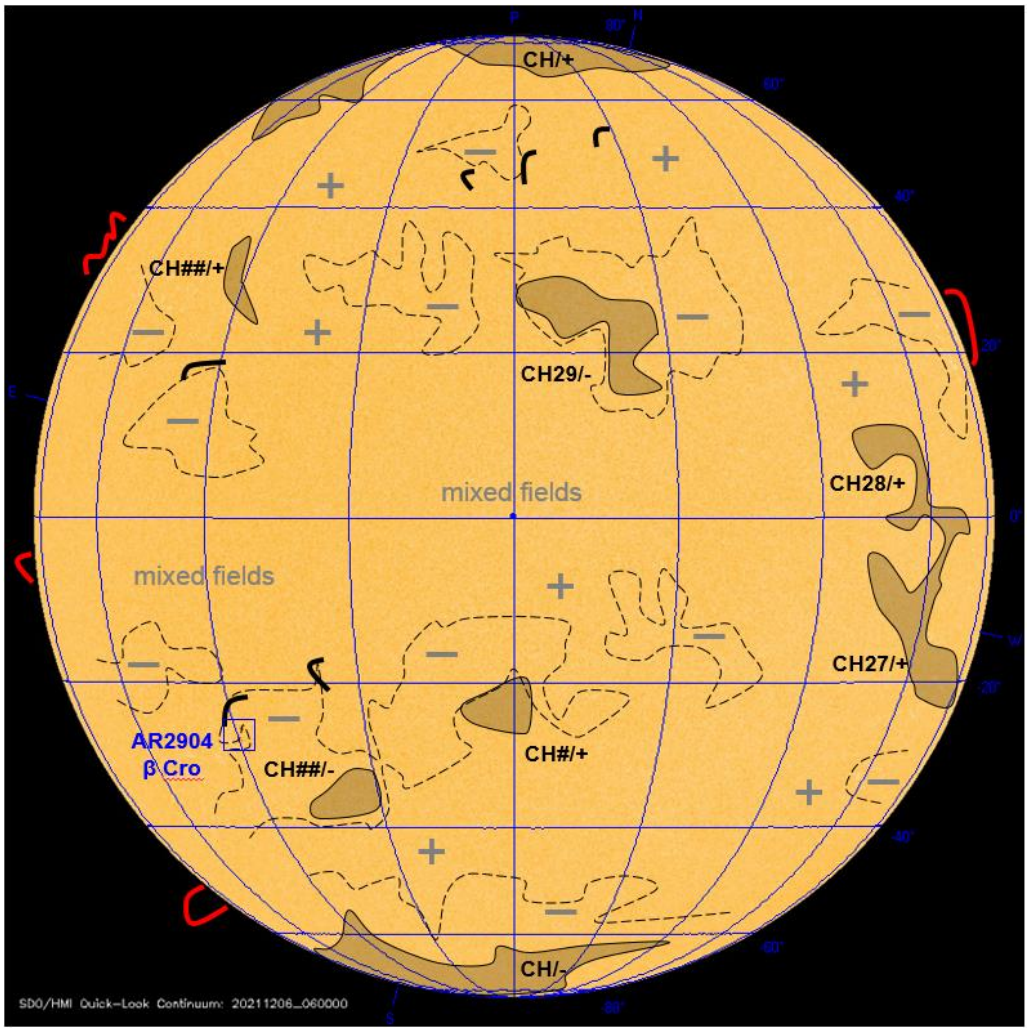
© Crown Copyright 2021. All Rights Reserved.

In terms of the unperturbed solar wind, the current fast wind from CH27/28 is expected to ease from day 2 onward (Tuesday 07 December), before a further fast wind enhancement is also possible towards the end of day 4 (Thursday 09 December) from CH29. All considered, there is a Slight Chance of G1 on day two from the probable near miss from the 03 December CME, with the period rounded out by a 20% Chance of G1 should the 05 December CME materialise, possibly polluting any signal from CH29.

Energetic Particles / Solar Radiation: The high energy (greater than 10 MeV) proton flux is expected to remain at Background levels.

The high energy electron flux (greater than 2 MeV) is likely to be at Moderate to High levels. The associated 24-hour integrated fluence is expected to persist below the Active threshold, but with a rising trend, giving a Chance of rising above, mainly day 1 or day 2 (Monday 06 or Tuesday 07 December). Confidence is low beyond the immediate term owing to the number of (potential) transients in the forecast.

Figure 1. Solar Analysis Valid 06/0600UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2021. All Rights Reserved.

Geomagnetic Storms:

There are two potentially Earth-directed CMEs in the forecast, as well as two further candidates (from recent disappearing filaments) awaiting imagery.

The first CME in the forecast is from a filament eruption on Friday 03 December, scheduled to pass 1AU as a near-miss of Earth on Tuesday 07 December. A placeholder 5% risk of G1 is included as a result. The second CME is a faint emission from a filament eruption on Sunday 05 December, and is expected to arrive day 4 (Thursday 09 December) at 09/1800UTC +/-9 hours, but again confidence is low due to limited imagery for analysis.

In terms of the unperturbed solar wind, the current fast wind from CH27/28 is expected to ease from day 2 onward (Tuesday 07 December), before a further fast wind enhancement is also possible towards the end of day 4 (Thursday 09 December) from CH29. All considered, there is a Slight Chance of G1 on day two from the probable near miss from the 03 December CME, with the period rounded out by a 20% Chance of G1 should the 05 December CME materialise, possibly polluting any signal from CH29.

Coronal holes of either polarity are near their semi-annual minimum potency at the minute, with Earth crossing the solar equatorial plane northwards on day three, Wednesday 08 December. minus any transient activity (confirmed or otherwise), the unperturbed wind and its effects ought to be unremarkable in the four-day period, as on previous rotations.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	1	5	1	20
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

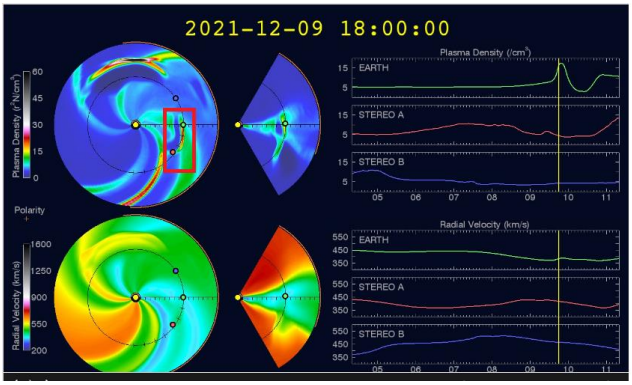
Geomagnetic Activity - Earthbound Coronal Mass Ejections

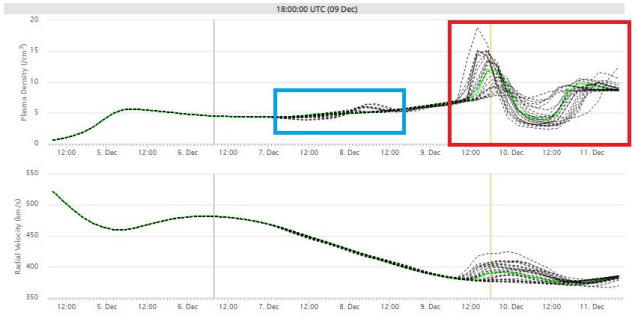
Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
03/12/2021 2347UTC	Partial	Filament eruption	NW quadrant	282	N/A	Near miss on Tuesday 07 December
05/12/2021 2337UTC	Partial	Filament Eruption	S hemisphere	325	09/1800UTC +/-9h	Limited imagery, low confidence, mainly below ecliptic.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2021. All Rights Reserved.

Figure 2: Latest MOSWOC Enlil run from 06/0800UTC, paused at the time the 05 December CME crosses 1AU around 09/1800UTC. The relevant ensemble is also shown, with this feature boxed red (as on density plot). Also shown is the probable near miss from the earlier 03 December CME in blue.





Radio Blackouts - X-Ray Flares:

Solar Activity became Low in the past 24 hours, with the chance of further observable flares from a narrowly far-sided active region quickly diminishing as it rotates further from 90W. The focus of future X-ray activity therefore returns to the Earth-side and the sole remaining sunspot region - AR2904. Whilst this group did go through a proliferation phase in the past 24 hours, this has now ceased for the time being, and the occasional C-class flares generated have stopped.

With no returning regions due over the eastern limb in the period, activity is forecast to be Low or Very Low, with only a daily Slight Chance (10%) of C-class flares.

X Ray Flares Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	R1-R2 M Class	No	1	1	1	1
Very Active	R3 to R5 X Class	No	1	1	1	1

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2021. All Rights Reserved.

Solar Radiation Storms - (High Energy Protons):

The high energy proton flux (greater than 10 MeV) as observed by GOES-16 is forecast to remain at background levels, with no solar radiation storms anticipated. Recent flares from the western solar horizon region have failed to register in terms of proton counts at GOES 16, and the risk of S1 or above is felt to remain low.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	1	1	1	1
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

High Energy Electrons Event (≥ 2MeV):

The high energy electron flux (greater than 2 MeV) as observed by GOES-16 has been varying between Moderate and High levels during the last 24 hours, and is forecast to persist at this level, with a low chance of seeing peak values increase day-to-day. There is also the potential for a dropout in values from any geomagnetic activity due to either the initial fast wind enhancement from CH27/28 or the subsequent low chance of a glancing CME on day 2 (7th). A further dropout in values is then likely towards the end of day 4 with the potential arrival of a further CME, alongside the chance of increased geomagnetic activity from the arrival of the fast wind of CH29.

The associated fluence is likely to rise a little day 1, but is likely to stay below the Active with only a slight chance of rising above. There is some uncertainty with the potential for a day-to-day increase of peak flux levels leading to fluence potentially approaching the Active threshold, however REFM is currently suggesting levels remain below it, in-line with this forecast.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	30	30	20	20
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2021. All Rights Reserved.